

of the fundamental nature of the airplane which is assumed to exist because the airplane behaves in flight in a certain consistent manner when the controls are placed in certain positions or are manipulated in a certain manner. In some cases, measurements of forces, control surface positions, or acceleration in pitch, roll, and yaw may be made to support a decision but normally it will be a pass/fail judgment by the FAA test pilot.

(2) Exceptional Skills. The phrase "exceptional piloting skill, alertness, or strength," is used repeatedly throughout the regulations and requires highly qualitative judgments on the part of the test pilot. The judgments should be based on the pilot's estimate of the skill and experience of the pilots who normally fly the type of airplane under consideration (that is, private pilot, commercial pilot, or airline transport pilot skill levels). Exceptional alertness or strength requires additional judgment factors when the control forces are deemed marginal or when a condition exists which requires rapid recognition and reaction to be coped with successfully.

(3) Stall Speed Multipliers. All flying qualities and trim speeds may be based on the forward c.g. stall speeds.

b. Procedures. None.

40.-44. RESERVED.

#### Section 4. CONTROLLABILITY AND MANEUVERABILITY

45. SECTION 23.143 (as amended by amendment 23-17) GENERAL.

a. Explanation.

(1) Temporary Control Forces. Temporary application, as specified in the table, may be defined as the period of time necessary to perform the necessary pilot motions to relieve the forces, such as trimming or reducing power. The values in the table under § 23.143 of Part 23 are maximums. There may be circumstances where a maximum pitch force less than 75 pounds is required for safety. For example, if a pilot is trying to overpower a nose-up malfunction during climb and reduce power at the same time, a maximum safe force may be less than 75 pounds. If it is found that a lower force is necessary for safety, then that lower force should be established under § 21.21(b)(2).

(2) Prolonged Control Forces. Prolonged application would be for some condition that could not be trimmed out, such as a forward c.g. landing. The time of application would be for the final approach only, if the airplane could be flown in trim to that point.

(3) Controllability. Controllability is the ability of the pilot, through a proper manipulation of the controls, to establish and maintain or alter the attitude of the airplane with respect to its flight path. It is intended in the design of the airplane that it be possible to "control" the attitude about each

of the three axes, the longitudinal, the lateral, and the directional axes. Angular displacements about the longitudinal axis are called "roll." Those about the lateral axis are called "pitch" and those about the directional axis are called "yaw." Controllability should be defined as "satisfactory" or "unsatisfactory." Unsatisfactory controllability would exist if the test pilot finds the controllability to be so inadequate that a dangerous condition might easily occur and is unacceptable as a showing of compliance with the regulations.

(4) Maneuverability. Maneuverability is the ability of the pilot, through a proper manipulation of the controls, to alter the direction of the flight path of the airplane. In order to accomplish this, it is necessary that the airplane be controllable, since a change about one of the axis is necessary in order to change a direction of flight. It should also be noted that any change in the direction of flight involves an acceleration normal to the flight path. Maneuverability is so closely related to controllability as to be inseparable in any real motion of the airplane. It is also similarly purely qualitative in its nature and should be treated in the same manner as has been suggested for controllability above.

(5) Spring Devices. If a spring device is installed in the control system, § 23.687 requires that the airplane not have any unsafe flight characteristics without the use of the spring device, unless the reliability of the device can be established by tests simulating service conditions.

b. Procedures.

(1) Landing. Using the AFM recommended approach/landing speeds and power settings, determine that airplane controllability is satisfactory with the wing flaps extended and retracted. These tests should be accomplished at the critical weight/c.g. combination within the allowable landing range. For turboprop airplanes, the engine fuel control should be adjusted to the minimum flight-idle fuel flow permitted on airplanes in service unless it is shown that the range of adjustment permitted on airplanes in service has no measurable effect on flight-idle sink rate.

(2) Other Flight Conditions. Controllability and maneuverability procedures for other flight conditions, such as takeoff and  $V_{MC}$ , are covered in their respective sections.

(3) Lateral Unbalance. Lateral fuel imbalance flight evaluations should be conducted on all airplanes where the wing fuel tanks are configured such that lateral trim and controllability may be affected by unbalanced fuel loadings. The following configurations should be considered and evaluated as appropriate:

(i) Takeoff - All engine, one-engine-inoperative (multiengine airplanes),  $V_{MC}$ , and crosswind operations.

(ii) En Route - All engine, one-engine-inoperative (multiengine airplanes), and autopilot coupled operations.

(iii) Approach and Landing - All engine, one engine inoperative (multiengine airplanes), crosswind, and autopilot coupled operations.

As a result of flight tests, appropriate lateral fuel imbalance limitations and procedures should be developed. Different values of fuel imbalance for the various flight configurations may be required. Imbalance limits, if any, should be included in the AFM.

c. Data Acquisition and Reduction. A qualitative determination by the test pilot will usually suffice unless the control force limits are considered marginal. In this case, force gauges are used to measure the forces on each affected control while flying through the required maneuvers.

46. SECTION 23.145 (as amended by amendment 23-17) LONGITUDINAL CONTROL.

a. Explanation.

(1) Elevator Power. This regulation requires a series of maneuvers to demonstrate the longitudinal controllability during pushovers from low speed, flap extension and retraction, and during speed and power variations. The prime determinations to be made by the test pilot are whether or not there is sufficient elevator power to allow pitching the nose downward from a minimum speed condition and to assure that the required maneuvers can be performed without the resulting temporary forces becoming excessive.

(2) Speeds Below Trim Speeds. The phrase, "speeds below the trim speed," as used in § 23.145(a), means speeds down to  $V_{S1}$ .

(3) Amendment 23-21 Revision Errors. Amendment 23-21 revised § 23.161 and deleted § 23.161(c)(4), among other changes. Sections 23.145(a)(2), 23.145(b)(4), 23.145(b)(6) and 23.145(d) were not updated to pick up the proper § 23.161 reference paragraphs. Sections 23.145(a)(2), 23.145(b)(4), 23.145(b)(6) and 23.145(d) should refer to § 23.161(c)(2), the approach condition.

(4) One Hand Control Force. The "exertion of more control force than can readily be applied with one hand for a short period of time," mentioned in § 23.145(b), is synonymous with the temporary application discussed in paragraph 45a(1) of this AC.

(5) Loss of Primary Control Systems. Section 23.145(e) is intended to cover a condition where a pilot has sustained some failure in the primary longitudinal control system of the airplane (for some multiengine airplanes, also loss of the directional control system) and is required to land using the power and trim system without the primary control. It is not intended that this test be demonstrated to an actual landing; however, a demonstration may be performed using manipulation of trim and power to a landing, if desired. Reference to § 23.677(b) makes it clear that § 23.145(e) is the flight test to demonstrate compliance with the requirement of § 23.677(b) which specifies a failure of the primary control system.

(6) Analysis of System. An analysis of the control system should be completed before conducting the loss of primary control system test. On some airplanes the required single longitudinal control system failure could result in loss of both the downspring and the primary longitudinal control system. If this

failure occurred on an airplane utilizing an extremely large downspring, the loss of the downspring may result in a nose-up pitching moment at aft c.g. that could not be adequately countered by the basic pitch trim system.

b. Procedures. The wording of the regulation sufficiently describes the maneuvers required to show compliance. The selection of altitudes, weights, and c.g. positions to be flight tested by the FAA will depend on a study of the applicant's flight test report. Normally, the following combinations are checked during the certification tests:

(1) Altitude. A low altitude and an altitude near the maximum altitude capability of the airplane. A high altitude may not be needed for normally aspirated engine airplanes.

(2) Weight. Maximum gross weight for all tests, except where otherwise described in subparagraph (3) below.

(3) C.G. Section 23.145(a), most aft c.g. and most aft c.g. approved for any weight; § 23.145(b) 1 through 6, most forward and most aft c.g.; § 23.145(c), most forward c.g.; § 23.145(d), most forward c.g. and most forward c.g. approved for any weight; and § 23.145(e), both the forward and aft c.g. locations. Section 23.145(e) is sometimes more difficult to achieve at the aft c.g. than the forward limit, particularly if the airplane exhibits neutral to divergent phugoid tendencies.

(4) Power or Configuration. Pitching moments resulting from power or configuration changes should be evaluated under all conditions necessary to determine the most critical demonstration configuration.

c. Data Acquisition. No special instrumentation is required. The exception to this would be the 10-pound force in § 23.145(d) which should be measured with a force gauge. All longitudinal forces should be measured if the forces are considered marginal or excessive.

#### 47. SECTION 23.147 (original issue) DIRECTIONAL AND LATERAL CONTROL.

##### a. Explanation.

(1) Engine Failure. Section 23.147(a) established a minimum maneuvering capability for an airplane that has sustained an engine failure after takeoff at a point in the climb-out path where the airplane has reached a speed of  $1.4 V_{S1}$ , or  $V_Y$  (applicant's option). This test assures enough aileron and rudder control to prevent loss of control during mild maneuvering which may be operationally necessary during climb-out after takeoff.

(2) Yawed Flight. Section 23.147(b) is intended as an investigation for dangerous characteristics during sideslip, which may result from blocked airflow over the vertical stabilizer and rudder. Rudder lock and possible loss of directional control are examples of the kinds of characteristics the test is aimed at uncovering. Section 23.177 also addresses rudder lock. Compliance may be demonstrated if the rudder stop is reached prior to achieving either  $15^\circ$  of heading

change or the 150-pound force limit providing there are no dangerous characteristics. The control stop serves more effectively than the 150-pound force to limit the pilot's ability to induce a yaw beyond that which has been demonstrated acceptable.

b. Procedures. The airplane configurations to be tested are:

- (1) One engine inoperative and its propeller in the minimum drag position.
- (2) The remaining engines at not more than maximum continuous power.
- (3) The rearmost allowable center of gravity.
- (4) The landing gear:
  - (i) retracted; and
  - (ii) extended.
- (5) The flaps in the most favorable climb position.
- (6) Maximum weight.
- (7) Airplane trimmed, if possible.

c. Data Acquisition. Data should be recorded as necessary to substantiate compliance. Forces may be estimated unless they are considered marginal.

48. SECTION 23.149 (as amended by amendment 23-21) MINIMUM CONTROL SPEED.

a. Background. Section 23.149 requires the minimum control speed to be determined. Section 23.1545 requires the airspeed indicator to be marked with a red radial line. Section 23.1583 requires that  $V_{MC}$  be furnished as an airspeed limitation in the AFM. These apply only to multiengine airplanes. A different  $V_{MC}$  airspeed will normally result from each approved takeoff flap setting. There are variable factors affecting the minimum control speed. Because of this,  $V_{MC}$  should represent the highest minimum airspeed normally expected in service. The variable factors affecting  $V_{MC}$  testing include:

(1) Engine Power.  $V_{MC}$  will increase as power is increased on the operating engine(s). Engine power characteristics should be known and engine power tolerances should be accounted for.

(2) Propeller of the Inoperative Reciprocating Engine. Windmilling propellers result in a higher  $V_{MC}$  than if the propeller is feathered.  $V_{MC}$  is normally measured with propeller windmilling unless the propeller is automatically feathered or otherwise driven to a minimum drag position without requiring pilot action.

(3) Propeller of the Inoperative Turbine Engine. Section 23.149c(5) requires the airplane to be in the most critical configuration when determining  $V_{MC}$ . The critical propeller configuration is usually windmilling. Many turbine-powered airplanes have automatically feathered (or otherwise driven to a minimum drag position) propellers which do not require pilot action.

(4) Control Position. The value of  $V_{MC}$  is directly related to the control surface travel available. Normally,  $V_{MC}$  is based on available rudder travel but may, for some airplanes, be based on aileron travel. For these reasons,  $V_{MC}$  tests should be conducted with rudder and aileron (if applicable) controls set at minimum travel. In addition, rudder and aileron control cable tensions should be adjusted to the minimum production tolerances. If during  $V_{MC}$  tests, control force limits would be exceeded at full deflection, then a lesser deflection should be used so as not to exceed § 23.143 force limits.

(5) Weight and C.G. For rudder limited airplanes with constant aft c.g. limits, the critical loading for  $V_{MC}$  testing is most aft c.g. and minimum weight. Aft c.g. provides the shortest moment arm relative to the rudder and thus the least restoring moments with regard to maintaining directional control.  $V_{MC}$  should be determined at the most adverse weight. Minimum practical test weight is usually the most critical, because the beneficial effect of banking into the operating engine is minimized. Light weight is also desirable for  $V_{MC}$  testing, because the stall speed is reduced.

(6) Fuel Loading. The maximum allowable fuel unbalance should be maintained.

b. Explanation.

(1) Controllability. The determination of  $V_{MC}$  is closely related to the controllability requirements. It is one of the maneuvers which generally requires maximum rudder and/or near maximum aileron deflection (unless limited by temporary control forces) to maintain airplane control. When minimum control speed is determined using maximum rudder deflection, limited airplane maneuvering is still available using the ailerons and elevator. When minimum control speed is determined using near maximum aileron deflection, the airplane may be incapable of further maneuvering in the normal sense.

(2) Critical Engine. The regulation requires that  $V_{MC}$  determination be made "when the critical engine is suddenly made inoperative." The intent is to require an investigation to determine which engine is critical from the standpoint of producing a higher  $V_{MC}$  speed. This is normally accomplished during static  $V_{MC}$  tests.

(3) Straight Flight. Straight flight is maintaining a constant heading. Section 23.149(a) requires the pilot to maintain straight flight (constant heading). This can be accomplished either with wings level or, at the option of the applicant, with up to 5° of bank toward the operating engine. Since 5° of bank allows the airplane to attain (or be closer to) zero sideslip, the 5° of bank is generally used as the option in certification.

(4) Control Forces. The rudder and aileron control force limits may not exceed those specified in § 23.143.

(5) Deicer Boots. The installation of deicer boots, antennas, and other external gear could change the  $V_{MC}$  speed significantly. Reevaluation of the  $V_{MC}$  speed should be considered when these installations are made. See AC 23.1419-1 if a "flight into icing" approval is being sought.

(6) Variable  $V_{MC}$ . For commuter category airplanes, a  $V_{MC}$  which varies with altitude and temperature is a permissible condition for use in determining § 23.53 takeoff speeds, provided that the AFM does not show a  $V_R$  below the red radial line speed required by § 23.1545(b)(6).

(7) Autofeather Annunciations. If autofeather is installed, there should be annunciations to advise of the status. This will include at least green advisory anytime the system is armed. For some airplanes, the autofeather system will be identified as a critical system. This could be because  $V_{MC}$  has been determined with an operative autofeather system or because commuter category takeoff conditions were predicated on an operative autofeather system. For such installations, additional annunciations may be necessary to ensure that the system is armed and that malfunctions are immediately recognized. This could include caution/warning/advisory annunciations as follows:

(i) Caution or warning, if autofeather switch is not armed.

(ii) Caution or advisory if the autofeather is armed, then is subsequently disarmed because of a system malfunction.

All annunciations should be evaluated to verify that they can be easily and quickly recognized. For critical systems, the AFM limitations should require a satisfactory preflight check and that the autofeather be armed for takeoff and landing.

#### c. Procedures.

(1) Configuration. Prior to conducting  $V_{MC}$  tests, rudder and aileron control travels should be set to the minimum allowable production travels. Rudder and aileron control cable tensions should be adjusted to the minimum value for use in service. The critical loading for  $V_{MC}$  testing is generally minimum weight and maximum aft c.g.; however, each airplane design should be evaluated independently to be assured that tests are conducted under the critical loading conditions. Variable aft c.g. limits as a function of weight, tip tanks, etc., can cause the critical loading condition to vary from one airplane to another.

(2) Power. An airplane with a sea-level engine will normally not be able to produce rated takeoff power at the higher test altitudes. Under these circumstances,  $V_{MC}$  should be determined at several power settings and a plot of  $V_{MC}$  versus power will allow extrapolation to determine  $V_{MC}$  at maximum takeoff power. See subparagraph c(6) for a further explanation of extrapolation methods. If tests are conducted at less than approximately 3000 feet density altitude, no corrections to  $V_{MC}$  are normally necessary. If tests are conducted above 3000 feet density altitude, then additional tests should be conducted to allow extrapolation to sea level thrust. Because propeller thrust decreases with increasing true airspeed,  $V_{MC}$  will increase with decreasing altitude and temperature, even at constant power.

The results of testing are used to predict the  $V_{MC}$  for a maximum takeoff power condition at sea level unless, because of turbocharging or other reasons, some higher altitude prevails as the overall highest  $V_{MC}$  value.

(3) Flap Settings. An applicant may want to specify more than one takeoff flap setting which would require  $V_{MC}$  investigation at each flap setting.

(4) Stalls. Extreme caution should be exercised during  $V_{MC}$  determination due to the necessity of operating with asymmetric power, full rudder, and aileron at speeds near the aerodynamic stall. In the event of inadvertent entry into a stall, the pilot should immediately reduce the pitch attitude, reduce power on the operating engine(s) and return rudder and aileron controls to neutral to preclude possible entry into a spin.

(5) Static Minimum Control Speed. The test pilot should select test altitude based on the capability to develop takeoff power and consistent with safe practices. It will be necessary to determine which engine is critical to the  $V_{MC}$  maneuver by conducting static tests with first one then the other engine inoperative to discover which produces the higher  $V_{MC}$ . Power should be set to the maximum available for the ambient condition. If possible, test weights should be light enough to identify the limits of directional control without stalling or being in prestall buffet.

For each test altitude condition, the following should be accomplished:

(i) Flaps. Set the flaps to the takeoff setting being investigated. The landing gear should be in the retracted position.

(ii) Trim. The airplane should be trimmed to the settings associated with normal symmetrical power takeoff.

(iii) Power. Set takeoff power on one engine and render the other engine inoperative. The propeller on the inoperative engine should be windmilling, or in the condition resulting from the availability of automatic feathering or other devices.

(iv) Controls. Gradually reduce airspeed until it is no longer possible to prevent heading changes with maximum use of the directional and near maximum use of the lateral controls, or the limit control forces have been reached. No changes in lateral or directional trim should be accomplished during the speed reduction. Usually the 5° bank option will be used (see paragraph 48b(3)) to maintain straight flight. A yaw string may be used to assist the test pilot in attaining zero sideslip (or minimum sideslip). The approximate ball deflection should be noted for inclusion in the AFM.

(v) Critical Engine. Repeat steps (i) thru (iv) to identify which inoperative engine results in the highest minimum control speed. If an autofeather system is installed and static  $V_{MC}$  was determined with the propeller feathered, repeat steps (i) thru (iv) with the critical engine inoperative and with the propeller windmilling.

(6) Extrapolation to Sea Level. The only  $V_{MC}$  test data that can be extrapolated reliably are static  $V_{MC}$  data, where most of the variables can be carefully controlled to a constant value. Because  $V_{MC}$  data are typically

collected in ambient conditions less critical than sea level standard day, extrapolation is nearly always necessary. Therefore, the usual way to establish an AFM  $V_{MC}$  is to extrapolate static  $V_{MC}$  data. Appendix 3 shows one method for extrapolating  $V_{MC}$  from test conditions to sea level standard day.

(7) Dynamic Minimum Control Speed. After determining the critical engine static  $V_{MC}$ , and at some speed above static  $V_{MC}$ , make a series of engine cuts (using the mixture control or idle cut-off control) dynamically while gradually working speed back toward the static  $V_{MC}$  speed. While maintaining this speed after a dynamic engine cut, the pilot should be able to control the airplane and maintain straight flight without reducing power on the operating engine. During recovery, the airplane should not assume any dangerous attitude nor should the heading change be more than  $20^\circ$  when a pilot responds to the critical engine failure with normal skill, strength, and alertness. The climb angle with all engines operating is high, and continued control following an engine failure involves the ability to lower the nose quickly and sufficiently to regain the initial stabilized speed. The dynamic  $V_{MC}$  demonstration will normally serve as verification that the numbers obtained statically are valid. If, in fact, the dynamic case is more critical, then the extrapolated static  $V_{MC}$  value should be increased by that increment. Frequently, the dynamic  $V_{MC}$  demonstration will indicate a lower  $V_{MC}$  than is obtained from static runs. This may be due to the fact that the inoperative engine, during spooldown, may provide net thrust or that control force peaks exceed limit values for a short period and go undetected or that due to high yaw and pitch angles and rates, the indicated airspeed values are erroneous. Because of the multi-variable nature of the dynamic  $V_{MC}$  demonstration, the AFM  $V_{MC}$  value should represent the highest of the static or dynamic  $V_{MC}$  test data, corrected to critical conditions.

(8) Repeatability. Once determined, the dynamic  $V_{MC}$  should be verified by running a series of tests to determine the speed is repeatable. The dynamic  $V_{MC}$  speed is the minimum control speed for the airplane. This speed may not exceed  $1.2 V_{S1}$  at maximum gross weight and the most unfavorable c.g. for stall speeds.

(9) AFM Minimum Control Speed Value.  $V_{MC}$  is usually observed at several different power settings and/or altitudes. Sufficient test data should be obtained such that the  $V_{MC}$  for the highest power and sea level density conditions may be determined. The  $V_{MC}$  resulting from this extrapolation to sea level is the one entered into the AFM and marked on the airspeed indicator. If this  $V_{MC}$  is determined with an autofeather system, the AFM required equipment list should list autofeather as a required item and the AFM would normally state the  $V_{MC}$  with the autofeather system inoperative (propeller windmilling) in the procedures section. The procedures section should also require the autofeather to be armed (if applicable) during takeoff and landing.

#### 49. SECTION 23.151 (original issue) ACROBATIC MANEUVERS.

a. Explanation. This regulation requires each maneuver to be evaluated and safe entry speeds established. Section 23.1567(c), which is associated with this requirement, imposes a requirement for a placard which gives entry airspeeds and approved maneuvers. If inverted flight is prohibited, the placard should so state.

b. Procedures. The applicant should fly each maneuver for which approval is sought. The FAA test pilot should then evaluate those maneuvers considered most critical.

c. Data Acquisition. A recently calibrated airspeed system, airspeed indicator, accelerometer, and tachometer should be provided by the applicant for the test airplane. The following should be recorded:

- (1) Load factor.
- (2) Entry airspeeds.
- (3) Maximum airspeeds.
- (4) Maximum r.p.m.

50. SECTION 23.153 (as amended by amendment 23-14) CONTROL DURING LANDINGS.

a. Explanation.

(1) Purpose. The purpose of this requirement is to ensure that airplanes over 6000 pounds gross weight do not encounter excessive control forces when approaching at a speed of 5 knots lower than normal landing approach speed. Also, a safe landing is required. Safe is considered to include having sufficient flare capability to overcome any excessive sink rate that may develop.

(2) Landing Requirements. Section 23.75 is a companion requirement and normally tests to determine compliance would be accomplished at the same time.

b. Procedures. The procedures applicable to § 23.75 would apply for § 23.153 except that for turbopropeller airplanes, the flight-idle fuel flow should be adjusted to provide minimum thrust.

51. SECTION 23.155 (as added by amendment 23-14) ELEVATOR CONTROL FORCE IN MANEUVERS.

a. Explanation.

(1) Stick Force Per G. The purpose of this requirement is to ensure that the positive stick force per g levels in a cruise configuration are of sufficient magnitude to prevent the pilot from inadvertently overstressing the airplane during maneuvering flight. The minimum maneuvering stability levels are generally found at aft c.g. loadings. Both aft heavy and aft light loadings should be considered. During initial inflight investigations, caution should be exercised in the event that pitch-up tendencies or decreasing stick force per g conditions occur.

(2) Buffet Boundaries. Low speed buffet onset may occur during high altitude investigations. A qualitative evaluation should be conducted beyond the boundary of buffet onset to ensure a capability to maneuver out of the buffet regime.

b. Procedures. Compliance with the requirements of § 23.155 should be demonstrated by measuring the normal acceleration and associated elevator stick force in a turn while maintaining the initial level flight trim speed. A descent may be required in the turn to maintain the level flight trim speed. As a minimum, the following conditions should be investigated in the cruise configuration; that is, flaps up and gear up (if retractable):

<u>Condition</u>	<u>Power</u>	<u>Level Flight Trim Speed</u>	<u>Altitude</u>
1	75% Maximum Continuous Power (reciprocating engine) or Maximum Cruise Power (turbine)	Trimmed (but not to exceed $V_{NE}$ or $V_{MO}/M_{MO}$ )	Low
2	75% Maximum Continuous Power (reciprocating engine) or Maximum Cruise Power (turbine)	Trimmed	Altitude for highest dynamic pressure (q)
3	75% Maximum Continuous Power (reciprocating engine) or Maximum Cruise Power (turbine)	$V_A$	Low
4	75% Maximum Continuous Power (reciprocating engine) or Maximum Cruise Power (turbine)	$V_A$	Highest attainable approved altitude

Compliance may be demonstrated by measuring the normal acceleration achieved with the limiting stick force or by establishing the stick force per g gradient and extrapolating to the appropriate limit. Linear stick force gradients may be extrapolated up to 0.5g maximum. Nonlinear stick force gradients that indicate a possible gradient lightening at higher g levels should not be extrapolated more than 0.2g.

c. Data Acquisition and Reduction. The following should be recorded for each test condition:

- (1) Wt./c.g.
- (2) Pressure altitude.
- (3) Outside air temperature (OAT).
- (4) Engine power parameters.
- (5) Trim setting.
- (6) Elevator force.

(7) Normal acceleration at c.g.

(8) Gear/flap position.

The test data should be presented in stick force versus g plots. Figure 51-1 shows a sample plot. Test results should be compared to the requirements of § 23.155(a).

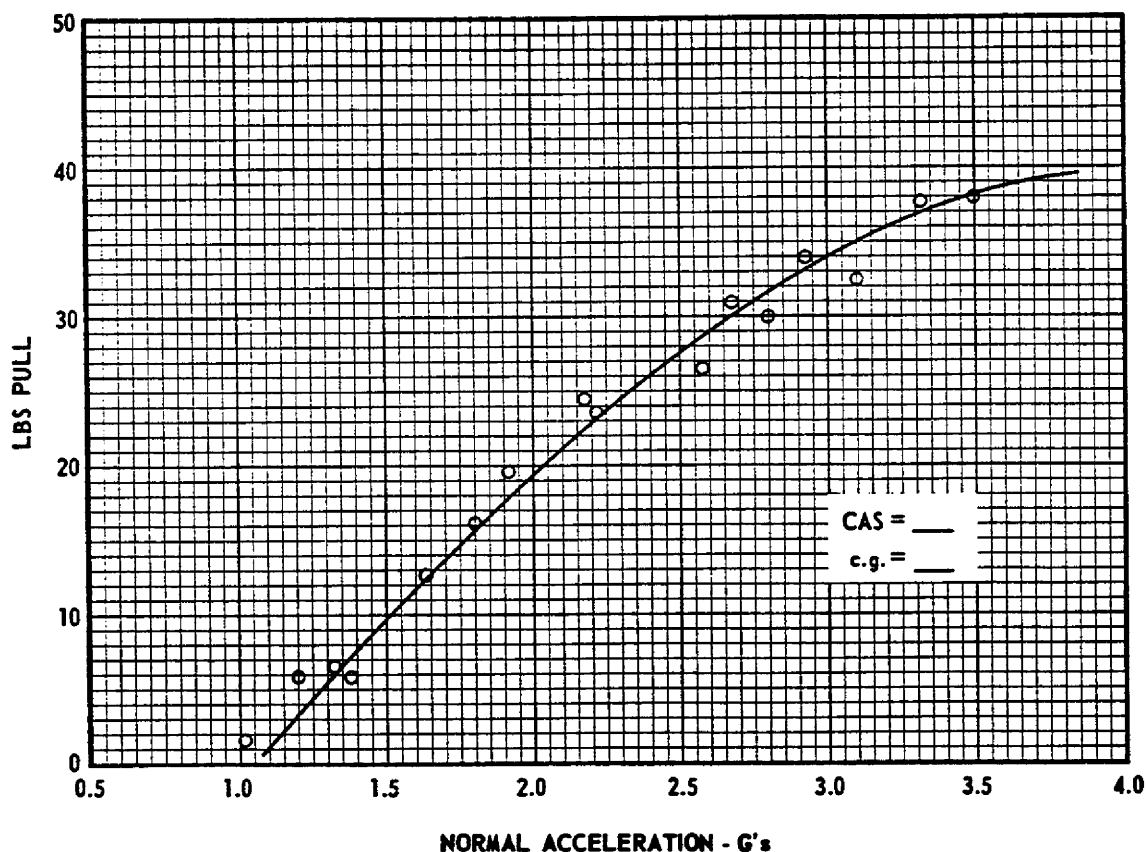


Figure 51-1 - Stick Force Per G

52. SECTION 23.157 (as added by amendment 23-14) RATE OF ROLL.

a. Explanation. The purpose of this requirement is to ensure an adequately responsive airplane in the takeoff and approach configuration.

b. Procedures.

(1) Bank Angle. The airplane should be placed in a  $30^\circ$  bank and rolled through an angle of  $60^\circ$ . For example, with the airplane in a steady  $30^\circ$  left bank, roll through a  $30^\circ$  right bank and measure the time. Sections 23.157(b) and (d) should be accomplished by rolling the airplane in both directions.

(2) Controls. Sections 23.157(a) and (c) permit using a favorable combination of controls. The rudder may be used as necessary to achieve a coordinated maneuver.

(3) Weight. The "W" in the formulas is the maximum weight.

c. Commuter Category Airplanes. The original intent of § 23.157 did not extend the formulas in the rule to a weight above 12,500 lbs. Extending the formulas above 12,500 lbs. would result in excessive roll times. Roll times for commuter category airplanes should not exceed the roll times allowed for airplanes weighing 12,500 lbs.

53.-62. RESERVED.

#### Section 5. TRIM

63. SECTION 23.161 (as amended by amendment 23-34) TRIM.

a. Explanation. The trim requirements ensure that the airplane will not require exceptional skill, strength, or alertness on the pilot's part to maintain a steady flight condition. The tests require the airplane to be trimmed for hands-off flight for the conditions specified. It should be noted that for single-engine airplanes, lateral-directional trim is required at only one speed and thus, ground adjustable tabs are acceptable. For lateral-directional testing, the tabs may be adjusted for the test trim airspeed and readjusted for subsequent tests. For multiengine airplanes, directional trim is required for a range of speeds. Lateral baggage loading and fuel asymmetry should be considered in this evaluation, if appropriate.

b. Procedures.

(1) Actuator Settings. Trim actuator travel limits should be set to the minimum allowable.

(2) Altitude and Power. Tests for trim should be conducted in smooth air. Those tests requiring use of maximum continuous power should be conducted at as low an altitude as practical to ensure attaining the required power.

(3) Weight and C.G. Longitudinal trim tests should be conducted at the most critical combinations of weight and c.g. Forward c.g. is usually critical at slow speeds, and aft c.g. critical at high speeds.

64.-69. RESERVED.

#### Section 6. STABILITY

70. SECTION 23.171 (original issue) GENERAL.

a. Explanation.

(1) Required Stability. The stability portion of Part 23 is primarily concerned with static stability. No quantitative values are specified for the degree of stability required. This allows simple test methods or qualitative

determinations unless marginal conditions are found to exist. The regulations merely require that the airplane be stable and that it have sufficient change in control force, as it is displaced from the trimmed condition, to produce suitable control feel for safe operation.

(2) Forces. The magnitude of the measured forces should increase with departure from the trim speed at any speed between the trim speed and those specified in § 23.175, rapidly enough for any substantial change in speed, through a change in the control forces, to be easily perceptible by the pilot. There shall be no reversal (that is, require forward push) in the control forces at any speed below the speeds specified in § 23.175 until the stalling speed is reached, that is, the control force shall in no case fall below zero before the stall is reached when trimmed as specified in § 23.175.

b. Procedures. None required for this section.

#### 71. SECTION 23.173 (as amended by amendment 23-34) STATIC LONGITUDINAL STABILITY.

a. Explanation.

(1) Demonstration Conditions. The general requirements of § 23.173 are determined from a demonstration of static stability under the conditions specified in § 23.175.

(2) Control Frictions. Section 23.173(b) effectively limits the amount of control friction that will be acceptable since excessive friction would have a masking effect on stability. If autopilot or stability augmentation systems are of such a design that they tend to increase the friction level of the longitudinal control system, critical static longitudinal stability tests should be conducted with the system installed. Control cable tensions should be set to the maximum.

(3) Stable Slope. Section 23.173(c) is an extremely general requirement which requires the test pilot's best judgment as to whether or not the stable slope of the stick force curve versus speed is sufficiently steep so that perceptibility is satisfactory for the safe operation of the airplane.

b. Procedures. Refer to paragraph 72.

#### 72. SECTION 23.175 (as amended by amendment 23-34) DEMONSTRATION OF STATIC LONGITUDINAL STABILITY.

a. Explanation. Section 23.175(b)(3) requires a power setting that will produce a speed for the trim point that is midway between the trim point used in testing high speed cruise and  $1.3 V_{S1}$ , which usually necessitates testing at the high speed cruise condition first.

b. Procedures.

(1) Section 23.175(a) Climb.

(i) Pull. The airplane should be trimmed in smooth air for the conditions required by the regulation. Tests should be conducted at the critical combinations of weight and c.g. Normally, light weight and aft c.g. are critical.

After observing trim speed, apply a light pull force and stabilize at a slower speed. Continue this process in increments of 10 to 20 knots, depending on the speed spread being investigated, until reaching minimum speed for steady unstalled flight. At some stabilized point, the pull force should be very gradually relaxed to allow the airplane to slowly return toward trim speed and zero stick force. Depending on the amount of friction in the control system, the eventual speed at which the airplane stabilizes will be somewhat less than the original trim speed. As required by § 23.173, the new speed, called free-return speed, must be within 10% (7.5% for commuter category airplanes in cruise) of the trim speed.

(ii) Push. Starting again at the trim speed, push forces should be applied and gradually relaxed in the same manner as previously described at speeds up to 115% of the trim speed and the same determination should be made.

(2) Other Stability Test Procedures. The balance of the stability requirements is flown using the same flight techniques described for climb stability, but using the configurations, trim points, and speed ranges being tested as described in each subparagraph.

c. Data Acquisition and Reduction. Force readings can be made with a hand-held force gauge, fish scale, or by electronic means, and plotted against calibrated airspeed to determine compliance with the regulation. See figure 72-1 for an example of the data plot. Section 23.179 allows for qualitatively determining that the stability requirements are met, but in most programs, force measurements are taken to substantiate longitudinal stability. Collect test data within a reasonable altitude band of the trim point altitude, such as  $\pm 2000$  feet.

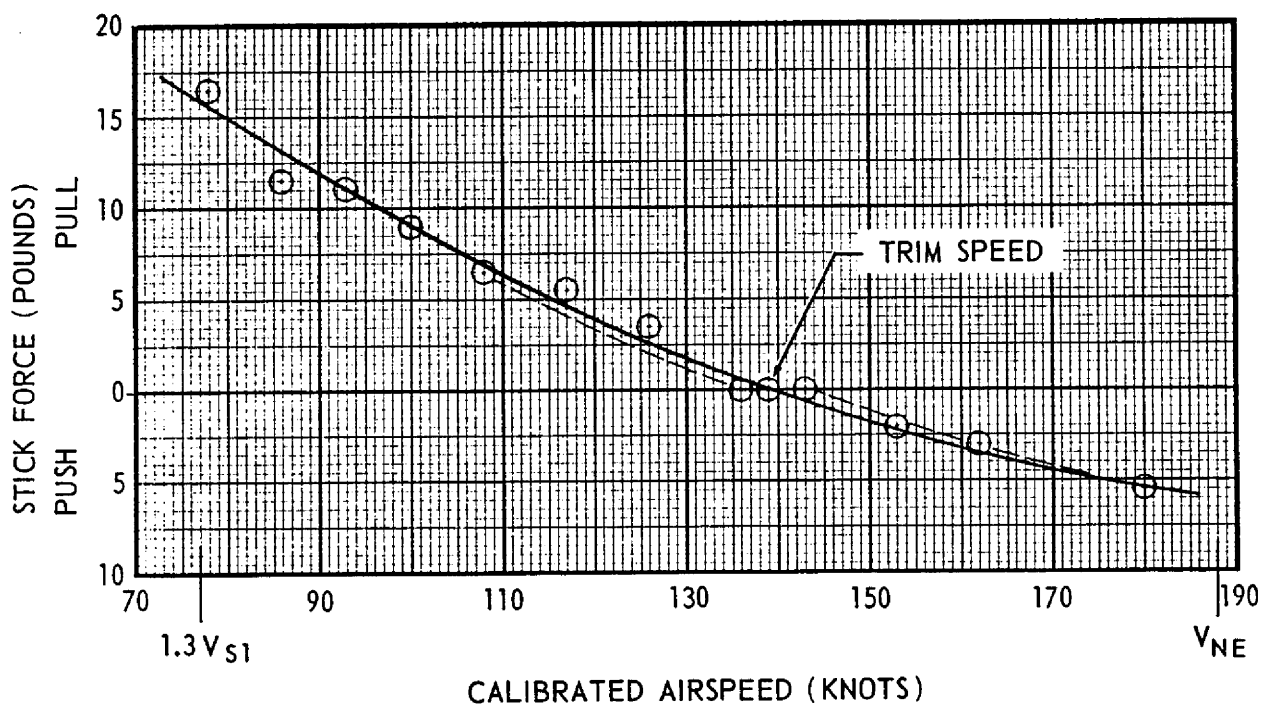


Figure 72-1 - STATIC LONGITUDINAL STABILITY PLOT (CRUISE CONDITION)

73. SECTION 23.177 (as amended by amendment 23-21) STATIC DIRECTIONAL AND LATERAL STABILITY.

a. Explanation.

(1) Purpose. The purpose of this section is to require positive directional and lateral stability for two- and three-control airplanes, and to verify the absence of rudder lock tendencies in three-control airplanes.

(2) Directional Stability. In § 23.177(a)(1), the determination of "appropriate" skid angles will depend on sound judgment in considering such things as airplane size, maneuverability, control harmony, and forces to determine the magnitude of skid angles the airplane will probably experience in service. Tests are continued beyond these "appropriate" angles up to the point where full rudder control is used or a force limit of 150 pounds, as specified in § 23.143, is reached. The rudder force may lighten but may not reverse. The rudder force tests are conducted at speeds between  $1.2 V_{S1}$  and  $V_A$ . The directional stability tests are conducted at speeds from  $1.2 V_{S1}$  to  $V_{NE}$  of the maximum allowable speed for the configuration, whichever is limiting.

(3) Lateral Stability (Dihedral Effect). The static lateral stability tests (reference § 23.177(a)(2)) take a similar approach in that the basic requirement must be met at the maximum sideslip angles "appropriate to the type of airplane." Up to this angle, the airplane must demonstrate a tendency to raise the low wing when the ailerons are freed. The static lateral stability may not be negative at  $1.2 V_{S1}$ .

(4) Forces. The requirement of § 23.177(a)(3) is to be tested at a speed of  $1.2 V_{S1}$  and larger than "appropriate" sideslip angles. At angles up to those which require full rudder or aileron control, or until the rudder or aileron force limits specified in the table in § 23.143 are reached, the rudder force may lighten but may not reverse.

(5) Two-Control Airplanes. For two-control airplanes, § 23.177(b)(1) is essentially a check of the adverse yaw characteristics with aileron input. A rapid roll from  $45^\circ$  of bank on one side to  $45^\circ$  on the other should not produce dangerous skid conditions.

(6) Spiral Stability. Section 23.177(b)(2) is a check of spiral stability. A dangerous attitude is construed to be  $60^\circ$  or more of bank,  $30^\circ$  or more of pitch, while a dangerous speed is  $V_{NE}$  or  $V_S$ .

(7) Autopilot or Stability Augmentation Systems (SAS). If autopilot or SAS are of such a design that they tend to increase the friction levels of the lateral and directional controls systems, then critical lateral and directional tests should be conducted with those systems installed.

b. Procedures.

(1) Altitude. The tests should be conducted at the highest practical altitude considering engine power and aerodynamic damping.

(2) Fuel Loading. The maximum allowable fuel unbalance should be maintained and both low fuel and full fuel loadings should be evaluated.

(3) Directional. To check static directional stability with the airplane in the desired configuration and stabilized on the trim speed, the airplane is slowly yawed in both directions keeping the wings level with ailerons. When the rudder is released, the airplane should tend to return to straight flight. See paragraph 63a for discussion of ground adjustable tabs.

(4) Lateral. To check lateral stability with a particular configuration and trim speed, conduct sideslips at the trim speed by maintaining the airplane's heading with rudder and banking with ailerons. See paragraph 63a for discussion of ground adjustable tabs. Section 23.177(a)(2) requires the slip angle to be appropriate to the type of airplane and the bank angle to be at least  $10^\circ$ . Some airplanes cannot maintain a heading in a slip with a  $10^\circ$  bank angle. In those cases, the slip should be performed with no less than a  $10^\circ$  bank and full opposite rudder and the heading allowed to vary. When the ailerons are released, the low wing should tend to return to level. The pilot should not assist the ailerons during this evaluation. The pilot should hold full rudder during the evaluation. The stability may be neutral at  $1.2 V_{S1}$ .

c. Data Acquisition. Data recorded should be sufficient for showing compliance.

74. SECTION 23.179 (original issue) INSTRUMENTED STICK FORCE MEASUREMENTS.

a. Explanation. None required.

75. SECTION 23.181 (as amended by amendment 23-21) DYNAMIC STABILITY.

a. Explanation - Longitudinal.

(1) Short Period. The short period oscillation is a qualitative evaluation and is the first oscillation the pilot sees after disturbing the airplane from its trim condition with the elevator control, as opposed to the long period oscillation (phugoid) which is sometimes excited along with the short period.

(2) Heavily Damped. For qualitative evaluations of longitudinal oscillations, the motion damping should appear "deadbeat;" that is, no residual oscillations that are perceptible to the pilot. If the damping is not "deadbeat," then an instrumented flight should be conducted and the airplane should be damped within two cycles after initial input. For lateral-directional oscillations (except Dutch roll), usually a qualitative evaluation will suffice, and the motion should be damped within two cycles.

b. Procedures - Longitudinal.

(1) General. The test for longitudinal dynamic stability is accomplished by a movement or pulse of the longitudinal control at a rate and degree to obtain a short period pitch response from the airplane. Initial inputs should be small and conservatively slow until more is learned about the airplane's response. Gradually, the inputs can be made large enough to evaluate more readily the airplane's oscillatory response and number of overshoots of the steady state condition.

(2) The Doublet. The "doublet input" excites the short period motion while suppressing the phugoid. It is generally considered to be the optimum means of exciting the short period motion of any airplane. The doublet input causes a deviation in pitch attitude in one direction (nose down), then cancels it with a deviation in the other direction (nose up). The total deviation in pitch attitude from trim at the end of a doublet is zero. Thus, the phugoid mode is suppressed. However, the short period motion will be evident since the doublet generates deviations in pitch rate, normal acceleration, and angle of attack at a constant airspeed. Short period characteristics may be determined from the manner in which these parameters return to the original trimmed conditions. The doublet is performed as follows:

(i) Flight Condition. Stabilize and trim carefully in the desired configuration at the desired flight condition.

(ii) Control Inputs. With a smooth, but fairly rapid motion, apply airplane nose-down longitudinal control to decrease pitch attitude a few degrees, then reverse the input to nose-up longitudinal control to bring the pitch attitude back to trim. As pitch attitude reaches trim, return the longitudinal cockpit control to trim and release it (controls-free short period) or restrain it in the trim position (controls-fixed short period). Both methods should be utilized. At the end of the doublet input, pitch attitude should be at the trim position (or oscillating about the trim position) and airspeed should be approximately trim airspeed.

(iii) Short Period Data. Obtaining quantitative information on short period characteristics from cockpit instruments is difficult and will be almost impossible if the motion is heavily damped. Short period oscillations are often of very low amplitude. If the pilot cannot see enough of the motion to measure and time a half-cycle amplitude ratio, the short period motion should be qualitatively described as essentially deadbeat. The influence of control system springs/bob-weights can be significant.

(iv) Input Frequency. The frequency with which the doublet input is applied depends on the frequency and response characteristics of the airplane. The test pilot should adjust the doublet input to the particular airplane. The maximum response amplitude will be generated when the time interval for the complete doublet input is approximately the same as the period of the undamped short period oscillation.

(v) Sequence of Control Inputs. The doublet input may be made by first applying aft stick, then reversing to forward stick. However, this results in less than 1g normal acceleration at the completion of the doublet and is more uncomfortable for the pilot.

(3) The Pulse Input. The pulse input also excites the short period nicely; however, it also tends to excite the phugoid mode. This confuses data analysis since the response of the airplane through the phugoid may be taken as a part of the short period response. This is particularly true for low frequency, slow-responding airplanes. Therefore, the pulse can usually only be utilized for high frequency, quick-responding airplanes in which the short period motion subsides before the phugoid response can develop. The pulse can always be used for a quick, qualitative look at the form of the short period motion. It is performed as follows:

(i) Flight Condition. Stabilize and trim in the desired configuration at the desired flight condition.

(ii) Control Inputs. With a smooth, but fairly rapid motion, apply airplane nose-up longitudinal control to generate pitchrate, normal acceleration, and angle of attack changes, then return the longitudinal control stick to the trim position. The short period motion may then be observed while restraining the control stick at the trim position (controls-fixed short period) or with the control stick free (controls-free short period).

(iii) Sequence of Control Inputs. Pulses may also be performed by first applying airplane nose-down longitudinal control.

(4) Dynamic Longitudinal Stability. Dynamic longitudinal stability should be checked under all the conditions and configurations that static longitudinal stability is checked; therefore, the test pilot may find it convenient to test for both on the same flights. It is not intended nor required that every point along a stick force curve be checked for dynamic stability; however, a sufficient number of points should be checked in each configuration to ensure compliance at all operational speeds.

c. Explanation - Lateral/Directional. Section 23.181(b) only requires investigation of the "Dutch roll" mode of the various lateral/directional couplings. Since the airplane responds in yaw through the Dutch roll mode every time it is disturbed in yaw, either by lateral gusts or by pilot inputs, the Dutch roll will be excited. The damping of the Dutch roll motion is probably the most important Dutch roll characteristic to be considered.

d. Procedures - Lateral/Directional. Two of the methods that may be used are described below:

(1) Rudder Pulsing. The rudder pulsing technique excites the Dutch roll motion nicely, while suppressing the spiral mode if performed correctly. In addition, this technique can be used to develop a large amplitude oscillation which aids in data gathering and analysis, particularly if the Dutch roll is heavily damped. It is performed as follows:

(i) Flight Condition. Stabilize and trim carefully in the desired configuration at the desired flight condition.

(ii) Control Inputs. Smoothly apply alternating left and right rudder inputs in order to excite and reinforce the Dutch roll motion. Restrain the lateral cockpit control at the trim condition or merely release it. Continue the cyclic rudder pulsing until the desired magnitude of oscillatory motion is attained, then smoothly return the rudder pedals to the trim position and release them (controls free) or restrain them (controls fixed) in the trim position.

(iii) Input Frequency. The frequency with which the cyclic rudder inputs are applied depends on the frequency and response characteristics of the airplane. The test pilot should adjust the frequency of rudder pulsing to the particular airplane. The maximum Dutch roll response will be generated when the rudder pulsing is in phase with the airplane motion, and the frequency of the rudder pulses is approximately the same as the natural (undamped) frequency of the Dutch roll.

(iv) Spiral Motion. The test pilot should attempt to terminate the rudder pulsing so that the airplane oscillates about a wings-level condition. This should effectively suppress the spiral motion.

(v) Data. Obtaining quantitative information on Dutch roll characteristics from cockpit instruments and visual observations requires patience, particularly if the motion is heavily damped. If instrumentation is available to record sideslip angle versus time, the dynamic characteristics of the maneuver can readily be determined. The turn needle of the needle-ball instrument can also be used to observe 1/10 amplitude damping and the damping period.

(2) Steady Sideslip. The steady sideslip release can also be used to excite the Dutch roll; however, the difficulty in quickly returning the controls to trim and the influence of the spiral mode often precludes the gathering of good quantitative results. Full rudder or a very large amplitude sideslip may cause high loads on the airplane. The rudder pulsing technique usually produces better Dutch roll data. The steady sideslip release technique is performed as follows:

(i) Flight Condition. Stabilize and trim carefully in the desired configuration at the desired flight condition.

(ii) Control Input. Establish a steady heading sideslip of a sufficient magnitude to obtain sufficient Dutch roll motion for analysis. Utilize maximum allowable sideslip, full rudder, or a comfortable rudder force input. Stabilize the sideslip carefully. Quickly, but smoothly, return all cockpit controls to trim and release them (controls-free Dutch roll) or restrain them at the trim position (controls-fixed Dutch roll). Both methods should be utilized.

e. Stability Augmentation Systems (SAS). If the airplane is equipped with SAS, the airplane's characteristics should be evaluated throughout the approved operating envelope, following failures which affect the damping of the applicable mode. Following a SAS failure, if unsatisfactory damping is confined to an avoidable flight area or configuration, and is controllable to return the airplane to a satisfactory operational condition for continued safe flight, the lack of

appreciable positive damping may be acceptable. Control of the airplane, including recovery, should be satisfactory using applicable control inputs. Following a critical failure, the degree of damping required should depend on the effect the oscillation will have on pilot tasks, considering environmental conditions. The capability to handle this condition should be demonstrated and evaluated. If a satisfactory reduced operational envelope is developed, appropriate procedures, performance, and limitations should be placed in the AFM. If a critical failure results in an unsafe condition, a redundant SAS may be required.

f. Data Acquisition and Reduction. Data acquisition for this test should support a conclusion that any short period oscillation is heavily damped and any Dutch roll is damped to 1/10 amplitude in 7 cycles.

76.-85. RESERVED.

## Section 7. STALLS

86. SECTION 23.201 (as amended by amendment 23-14) WINGS LEVEL STALL.

### a. Explanation.

(1) Stall. Section 23.201(c) defines when the airplane can be considered stalled, for airplane certification purposes. When either of two conditions occurs, whichever occurs first, the airplane is stalled. The conditions are:

- (i) Uncontrollable downward pitching motion; or
- (ii) the control reaches the stop.

Additionally, for airplanes with a stall barrier system, stick pusher operation has been considered as the stall speed. The term "uncontrollable downward pitching motion" is the point at which the pitching motion can no longer be arrested by application of nose-up elevator and not necessarily the first indication of nose-down pitch. Figure 17-1 shows a graphic representation of stall speed time histories for various configurations.

(2) Related Sections. The stalled condition is a flight condition that comes within the scope of §§ 23.49, 23.141, 23.143(b), 23.171, and 23.173(a). Section 23.143(b) requires that it be possible to effect a "smooth transition" from a flying condition up to the stalled flight condition and return without requiring an exceptional degree of skill, alertness, or strength. Any need for anticipated or rapid control inputs exceeding that associated with average piloting skill, is considered unacceptable.

(3) Recovery. The flight tests include a determination that the airplane can be stalled and flight control recovered, with normal use of the controls. Section 23.201(a) requires that for airplanes with independent roll and directional controls, it must be possible to produce and correct roll by unreversed use of the roll control and to produce and correct yaw by unreversed use of the directional control.

(4) Power. The propeller condition for the "power-off" tests prescribed by § 23.201(f)(6) should be the same as the "throttles closed" condition prescribed for the stalling speed tests of § 23.49, that is, propellers in the takeoff position, engine idling with throttles closed. The alternative of using sufficient power to produce zero propeller thrust does not apply to stall characteristics demonstrations.

(5) Altitude Loss. Altitude loss in excess of 100 feet and nose-down pitch in excess of 30° will be entered in the performance information section of the AFM in accordance with § 23.1587(a)(1) for the wings level stalls. The power used to regain level flight may not be applied until flying control is regained. This is considered to mean not before a speed of  $1.2 V_{S1}$  is attained in the recovery dive.

(6) Configurations. Stall characteristics should be evaluated:

(i) At maximum to minimum weights at aft c.g. Aft light loadings may be the most critical in airplanes with high thrust to weight ratios.

(ii) With the elevator up stop set to the maximum allowable deflection.

(iii) With maximum allowable fuel unbalance.

(iv) At or near maximum approved altitude.

Also, airplanes with de-rated engines should be evaluated up to the critical altitude of the engine and at maximum altitude for which the airplane is to be certified. An airplane may be approved if it has stick pusher operation in one configuration, such as power on, and has acceptable stall characteristics for the remaining configurations.

b. Procedures.

(1) Emergency Egress. It is the responsibility of the applicant to provide adequate provision for crew restraint, emergency egress and use of parachutes (reference § 21.35(d)).

(2) Buildup. The FAA test pilot should carefully review the applicant's flight test report on stall and recovery characteristics. Generally, the stalls at more rearward c.g. positions are more critical than at the forward c.g. position. For this reason, the stall characteristics at forward c.g. should be investigated first. Altitude should be low enough to ensure capability of setting 75% power, but high enough to accomplish a safe recovery. The 75% power requirement means 75% of the rated power adjusted to the temperature and altitude test conditions. Reciprocating engine tests conducted on a hot day, for example, would require higher manifold pressures to be set so that when chart brake horsepower is adjusted for temperature, the result is 75% power.

(3) Pilot Determinations. During the entry and recovery, the test pilot should determine:

(i) That the stick force curve remains positive up to the stall (that is, a pull force is required) (reference § 23.173(a)) when the trim speed is higher than the stall speed.

(ii) That it is possible to produce and correct roll and yaw by unreversed use of the rolling and directional control.

(iii) The altitude loss.

(iv) The pitch attitude below level.

(v) The amount of roll or yaw encountered during the recovery.

(vi) For two-control airplanes with interconnected lateral and directional controls, that it is possible to produce and correct roll up to the stall without producing what, in the opinion of the test pilot, is considered as "excessive yaw."

(4) Speed Reduction Rate. Section 23.201(c) requires the rate of speed reduction for entry not exceed one knot per second.

c. Data Acquisition and Reduction.

(1) Instruments. The applicant should provide a recently calibrated sensitive altimeter, airspeed indicator, accelerometer, outside air temperature gauge, and appropriate propulsion instruments; such as a torque meter or manifold pressure gauge and tachometer, a means to depict roll, pitch, and yaw angles; and force gauges when necessary.

(2) Data Recording. Automatic data recording is desirable, but not required, for recording time histories of instrumented parameters and such events as stall warning, altitude loss, and stall break. The analysis should show the relationship of pitch, roll, and yaw with respect to various control surface deflections. (See figure 17-1, stall speed determination.)

d. Stick Pusher.

(1) Background. Stick pushers have been installed in some airplanes which would not meet the requirements of § 23.201. This was accomplished under the provisions of § 21.21b(1). In some airplanes, operation of the stick pusher was not critical to safe flight and in others, stick pusher performance was essential to safe flight. In the latter case, the stick pusher typically functions as a stall barrier to prevent an airplane from entering flight regimes where a nonrecoverable stall could occur.

(2) Stall Prevention. There are two basic situations where a stick pusher would be necessary to show compliance with regulations. These are:

(i) Airplane Recoverable. The stall characteristics are investigated and during these tests, the airplane does not meet regulatory requirements but an inadvertent aerodynamic stall would not be catastrophic or

require exceptional piloting skill to recover. For example, during certain conditions of c.g., weight, or power, the airplane exceeds the 15° roll limit because of excessive angle of attack or other conditions. The pusher is installed and designed to function at some angle of attack where the 15° of roll will not be exceeded. If this pusher system fails to function, the airplane is still recoverable from the stalled flight condition. For this system, the occurrence of a failure should be evaluated for an unsafe condition.

(ii) Airplane Not Recoverable. When the airplane is not capable of recovering from stalls or the applicant chooses not to investigate the consequences of stalling demonstrations with the pusher system rendered inoperative, then if the stick pusher fails to perform its intended function, an unsafe condition would exist.

(3) System Tolerances. Stick pusher system(s) tolerances should be evaluated and accounted for during certification flight tests. The applicant normally specifies the system tolerances in terms of plus or minus so many knots. The system(s) should be set to the minus (lowest stall speed) side of the tolerance when investigating stall characteristics and minimum longitudinal trim capability. The system(s) should be set to the plus (highest stall speed) side of the tolerance for stall speed determination and for determining performance stall speed multiples. Alternately, a nominal stick pusher stall speed may be used when it is determined that stick pusher tolerances result in no more than 3 knots or 5% variation in stall speed, whichever is greater.

(4) Airspeed Margins. The airspeed margin between unsatisfactory stall characteristics and the minimum stick pusher actuation speed, for identical flight conditions, should be evaluated. The following information is provided as a guide. For airplanes with unsatisfactory, hazardous or unrecoverable aerodynamic stall characteristics, the minimum speed margin between aerodynamic stall and minimum stick pusher systems actuation speed should not be less than 5 knots. For other airplanes with known and less hazardous aerodynamic stall characteristics, the speed margin may be reduced to not less than 2 knots.

(5) Preflight Check. If a reliability credit is to be given for a preflight check, the following should be evaluated:

(i) The check includes the functioning of the complete system, including the incidence sensors, so all faults would be detected.

(ii) The check is easily conducted, and requires little pilot time or effort.

(iii) A note in the limitations section of the AFM requires the check to be accomplished prior to flight.

(iv) The AFM identifies the criticality of the system and the need to accomplish the preflight check.

(6) Inadvertent Operation. Inadvertent stick pusher operation should be extremely improbable or investigated and shown not to be hazardous and to be recoverable.

87. SECTION 23.203 (as amended by amendment 23-14) TURNING FLIGHT AND ACCELERATED STALLS.

a. Explanation.

(1) Explanations 86a(2) and (4) for wings level stalls also apply to turning flight and accelerated stalls.

(2) The only differences between the investigation required for turning flight and accelerated stalls are in the speed reduction rate and wing flap configurations.

b. Procedures.

(1) Procedure 86b(1) for wings level stalls applies to turning flight and accelerated stalls.

(2) During the maneuver, the test pilot should determine:

(i) That the stick force remains positive up to the stall.

(ii) That the altitude lost is not, in the test pilot's opinion, excessive.

(iii) There is no undue pitchup.

(iv) That there are no uncontrollable spinning tendencies; i.e., while the airplane may have a tendency to spin, a spin entry is readily preventable.

(v) That the test pilot can complete the recovery with normal use of the controls and average piloting skill.

(vi) Roll did not exceed  $60^{\circ}$  incremental in either direction.

(vii) For accelerated stalls, maximum speed or limit load factors were not exceeded.

(3) Section 23.203(a) requires the rate of speed reduction for a turning flight stall not exceed one knot per second; for an accelerated stall, 3 to 5 knots per second with steadily increasing normal acceleration.

c. Data Acquisition. Same as for wings level stalls.

88. SECTION 23.205 (as amended by amendment 23-14) CRITICAL ENGINE INOPERATIVE STALLS.

a. Explanation.

(1) Undue Spinning. In addition to the other stall requirements, for multiengine airplanes, § 23.205(a) requires that there be no undue tendency to spin when stalled from an unaccelerated wings level entry with the critical engine

inoperative. An "undue spinning" tendency would be considered to exist when other than normal use of the controls or exceptional skill, strength, or alertness were required to prevent spinning. In this case, reduction of power on the operating engine(s) during recovery, would be considered normal use of the controls.

(2) Power. Section 23.205(b)(4) states, ". . . the remaining engine(s) at 75% maximum continuous power or thrust, or the power or thrust at which the use of maximum control travel just holds the wings laterally level in the approach to stall . . . ." This section states that if use of maximum rudder or aileron control cannot maintain a wings level attitude prior to the stall, the power may be reduced from 75% MCP to a point where maximum control travel just maintains wings level approaching the stall. The intent of this section is to check one-engine-inoperative stall characteristics, not engine-out lateral directional control capability which is covered under tests for  $V_{MC}$ .

(3) Propeller. If propeller feathering is available (manual or automatic), the propeller on the inoperative engine should be feathered.

b. Procedures. With the airplane trimmed longitudinally as specified in § 23.205(b)(6), with the critical engine inoperative, gear and flaps up, and 75% MCP on the operating engine, conduct a wings level stall by reducing the airspeed with the elevator control at a rate not greater than 1 knot per second. Keep the wings level and heading constant up to the stall. If there is insufficient control to do so, discontinue the maneuver and start over with reduced power on the operating engine. The power reduction should be just enough to allow keeping wings level and heading constant with full control travel. The operating engine(s) may be throttled back during the recovery, but care should be exercised to reduce previous control inputs as the power is reduced. Record the altitude loss incurred during the stall in compliance with § 23.1587(c)(1). The stalls should be accomplished in smooth air.

c. Data Acquisition. Same as for other wings level stalls of § 23.201.

## 89. SECTION 23.207 (as amended by amendment 23-7) STALL WARNING.

### a. Explanation.

(1) Purpose. The purpose of this requirement is to ensure an effective warning in sufficient time to allow a pilot to recover from an approach to a stall without reaching the stall.

(2) Types of Warning. The effective warning may be from either aerodynamic disturbances or from a reliable artificial stall warning device such as a horn or a stick shaker. The aerodynamic warning is usually manifested by a buffet which vibrates or shakes the airplane. The type of warning should be the same for all configurations.

(3) Artificial Stall Warning. Stall warning devices may be used in cases where there is inadequate aerodynamic warning. The warning signal from the devices should be clear and distinctive and not require the pilot's attention to be directed inside the airplane. A stall warning light by itself is not acceptable.

(4) Margin. The stall warning margin between 5 knots and the greater of 10 knots or 15% of the stalling speed, is applicable when the speed is reduced at the rate of one knot per second. Stall warning margin at greater deceleration rates should not be less than 5 knots above the stall or above a speed at which warning would become objectionable in the normal operating range.

b. Procedures. The stall warning tests should be conducted in conjunction with the stall tests required by §§ 23.201 and 23.203.

c. Data Acquisition and Reduction. The speed at which stall warning is obtained should be recorded. This speed should be compared to the corresponding stall speed for the required stall warning margin of between 5 and the greater of 10 knots or 15% of the stalling speed above the corresponding stalling speed.

90.-99. RESERVED.

## Section 8. SPINNING

### 100. SECTION 23.221 (as amended by amendment 23-7) SPINNING.

#### a. Explanation.

(1) Spin. A spin is a sustained auto rotation at angles of attack above stall. The rotary motions of the spin may have oscillations in pitch, roll and yaw superimposed upon them. The fully-developed spin is attained when the trajectory has become vertical and the spin characteristics are approximately repeatable from turn to turn. Some airplanes can autorotate for several turns, repeating the body motions at some interval, and never stabilize. Most airplanes will not attain a fully-developed spin in one turn.

(2) Category Spins. Section 23.221 addresses four situations:

(i) Normal category spins.

(ii) Utility category spins.

(iii) Acrobatic category spins.

(iv) Airplanes characteristically incapable of spinning.

(3) Incapable of Spinning. If an airplane cannot be induced to spin, it may be considered "characteristically incapable of spinning." Section 23.221(d) gives the conditions of the test for this type of airplane.

(4) Utility Category Spins. Utility category airplanes must meet the spin requirements of either the normal or acrobatic category. Thus, the spin requirements reduce to either normal or acrobatic category requirements, each with its own objectives and tests.

b. Discussion and Procedures Applicable to Both Normal and Acrobatic Category Spins.

(1) Weight and C.G. Envelope. See paragraph 7a of this AC for discussion of weight and c.g. envelope exploration.

(2) Control Deflections. Control surface deflections should be set to the critical side of the allowable tolerances, for example, if the rudder deflection is  $20^{\circ} + 2^{\circ}$  left and right, it should be rigged at  $18^{\circ}$  left and right for the testing if the recovery phase is critical or  $22^{\circ}$  left and right if the entry phase is critical.

(3) Emergency Egress. It is the responsibility of the applicant to provide adequate provision for crew restraint, emergency egress and use of parachutes (reference § 21.35(d)).

(4) Chutes and Ballast. A spin chute that has been structurally and functionally tested is recommended. NASA Technical Paper 1076, "Spin-Tunnel Investigation of the Spinning Characteristics of Typical Single-Engine General Aviation Airplane Designs," dated November 1977, may be of assistance in sizing the spin chute. In the past, rapidly movable jettisonable ballasts have been suggested but this may not effect recovery in practical use. Final certification of the spin characteristics should be conducted with the external spin chute removed unless it is determined that spin chute installation has no significant effect on spin characteristics.

(5) Build-Up. When any doubt exists regarding the recovery characteristics of the test airplane, a build-up technique should be employed consisting of spin entries and recoveries at various stages as the maneuver develops. Excessive aerodynamic control wheel back pressure indicates a possibility of unsatisfactory spin characteristics. Any control force lightening or reversal is an indication of possible deep stall entry. See subparagraph c(7) for definition of excessive back pressure. A yaw rate instrument is valuable in detecting progress toward a fully-developed spin condition or an uncontrollable maneuver. Unusual application of power or controls has sometimes been found to induce uncontrollable spins. Leading with elevator in recovery and cutting power as the airplane rolls into a spin have been known to induce uncontrollable spins.

(6) Entry. Spins should be entered in the same manner as the stalls in §§ 23.201 and 23.203 with trim at  $1.5 V_{S1}$  or as close as practical. As the airplane stalls, with ailerons neutral, apply full-up elevator and full rudder in the direction of spin desired. Refer to paragraphs 100c and 100d for further discussion of spin entries.

(7) Recovery. Recoveries should consist of throttle reduced to idle, ailerons neutralized, full opposite rudder, followed by forward elevator control as required to get the wing out of stall and recover to level flight, unless the manufacturer determines the need for another procedure.

(8) Trimmable Stabilizer. For airplanes that trim with the horizontal stabilizer, the critical positions should be investigated.

(9) Altitude Engines. For airplanes with high-altitude engines, the effect of altitude should be investigated.

(10) Initial Investigation. In all cases, the initial spin investigation should be accomplished at as high an altitude above the ground as reasonably possible and a predetermined, pre-briefed "hard" altitude established to be used as the emergency egress altitude. In other words, if the airplane cannot be recovered by that altitude, all occupants should exit the airplane without hesitation. The altitude selected should take into account the opening characteristics of the parachutes, the difficulty of egress, the estimated number of turns to get out and the altitude loss per turn, the distance required to clear the airplane before deploying the parachutes, etc.

c. Discussion and Procedures Applicable to Normal Category Spins.

(1) Objective. The basic objective of normal category spin testing is to assure that the airplane will not become unrecoverable within one turn if a spin should be encountered inadvertently and that recovery can be effected without exceeding the airplane design limitations. Type certification testing requires recovery capability from a one-turn spin while operating limitations prohibit intentional spins. This one-turn "margin of safety" is designed to provide adequate controllability when recovery from a stall is delayed. Section 23.221(a) does not require investigation of the controllability in a true spinning condition for a normal category airplane. Essentially, the test is a check of the controllability in a delayed recovery from a stall. Intentional, inadvertent, normal, and accelerated stalls should be considered.

(2) Uncontrollable Spins. Uncontrollable spins for normal category airplanes are defined as spins that persist after normal recovery control application is completed and one additional turn has passed. For example, if you are spinning left with right aileron (abnormal controls), recover by reducing power to idle, neutralize the ailerons, apply full right rudder followed by forward elevator. At this point, start the count (heading, ground reference, etc.) for one turn. If the manufacturer's recommended spin recovery procedure has a contingency step, such as, "apply forward elevator after rotation stops," then the count should start after the rotation stopping control is applied.

(3) Abnormal Control. The "abnormal" use of controls should not cause the airplane to become uncontrollable. "Pro-spin" is used to describe the use of the controls in the direction of the spin and is considered normal use of the controls; i.e., spinning left with left aileron, full back elevator, full left rudder and power on. "Anti-spin," "aileron against," and "abnormal use of controls" is control usage that is opposite the normal usage of controls. These conditions of control position would be expected to reduce the tendency to spin but, in fact, may aggravate or make the spin worse. The intent of all these tests is to induce all of the types of control usage, whether they are right or wrong, that might be used during the operation of the airplane. Ailerons with and against the spin should be applied at entry and during spins. Elevator and rudder against the spin should be applied during the spin.

(4) Spin Matrix. The effects of gear, flaps, power, accelerated entry, and control abuse should be investigated. A suggested matrix for spin investigation is given in figure 100-1. It is the responsibility of the applicant to explore all critical areas. It may be possible to eliminate the need to conduct some of the additional conditions once the airplane responses are known.

(5) Flaps. Flaps may be retracted after rotation ceases and the dive and pull-out are entered.

(6) Power. For power on normal category spins, the throttle can be reduced to idle after one turn.

(7) Back Pressure. Excessive back pressure is cause for noncompliance. Excessive back pressure is a judgment item and is defined as excessive force required to pitch the airplane down in recovery. Back pressure should not interfere with prompt and normal recovery.

d. Discussion and Procedures Applicable to Acrobatic Category Spins.

(1) Objective. The basic objective of acrobatic category spin testing is to ensure that the airplane will not become uncontrollable when a spin is intentionally entered and:

(i) The controls are used abnormally (as well as normally) during the entry and/or during the spin;

(ii) the airplane will recover in not more than 1 1/2 turns after completing application of normal or manufacturer-prescribed recovery controls; and

(iii) no airplane limitations are exceeded, including positive maneuvering load factor and limit speeds.

(2) Pilot Training. It is assumed that the pilot of the acrobatic category airplane that spins for six turns is doing so intentionally. If spinning is intentional, the pilot should have had proper instruction and proficiency to effect a proper recovery. The pilot should be expected to follow the published procedure to recover from this planned maneuver.

(3) Uncontrollable Spins. Uncontrollable spins are defined as spins that persist after the normal recovery technique is applied and 1 1/2 additional turns have passed. The discussion of "abnormal" use of controls in paragraph 100c(3) also applies to acrobatic category spins.

(4) Spin Matrix. The effects of gear, flaps, power, accelerated entry, and normal and abnormal control use should be investigated. A suggested matrix for spin investigation is given in figure 100-1. It is the responsibility of the applicant to explore all critical areas. It is necessary to expand the matrix to cover six-turn spins. The normal procedure is to continue the same process and add one additional turn each time. It may be possible to eliminate the need to conduct some of the additional conditions once the airplane responses are known.

SPIN EVALUATION  
CONFIGURATION

Flight Condition	Spin Number	Flaps Up	Flaps Appch. (As Approp.)	Flaps Landing	Gear Up	Gear Down	Cowl Flaps Closed	Cowl Flaps As Required	Power Off	Power On	Forward C.G.	Aft C.G.	Lateral C.G.	Slow Elevator Releases
Test with Normal Spin Controls	1	X			X		X		X		X	X	X	
	2		X			X	X				X	X	X	
	3			X		X	X	X			X	X	X	
	4	X			X					X	X	X	X	
	5		X			X		X		X	X	X	X	
	6			X		X		X		X	X	X	X	
Repeat 1 Through 6 from a right spin.														
Repeat 1 through 6 from left and right turning flight.														
Tests with Abnormal Spin Controls	7	X			X		X		X		X	X	X	X
Left Spin Alleron Against 7 Thru 12	8		X			X	X		X		X	X	X	X
	9			X		X	X		X		X	X	X	X
	10	X			X					X	X	X	X	X
	11		X			X				X	X	X	X	X
Left Spin Alleron with 13 Thru 18	12			X		X		X		X	X	X	X	X
	13	X			X		X		X		X	X	X	X
	14		X			X	X		X		X	X	X	X
	15			X		X	X		X		X	X	X	X
	16	X				X	X		X		X	X	X	X
	17		X			X	X		X		X	X	X	X
	18			X		X	X	X		X	X	X	X	X
Repeat 13 Through 18 From a Right Spin														
Repeat 7 Through 18 From Left & Right Turning Flight														

Figure 100-1 - SPIN EVALUATION CONFIGURATION MATRIX

(5) Spiral Characteristics. The acrobatic spin requirement stipulates that for the flap retracted six-turn spin, the spin may be discontinued after 3 seconds if spiral characteristics appear. This does not mean that the spin test program is discontinued. Each test point should stand alone and that spin be discontinued only after a spiral has developed. Limit speed should not be exceeded in the recovery. The airplane may be certificated as an acrobatic airplane whether or not it can spin a minimum of six turns.

(6) Power. For power on acrobatic spins, the throttle can be reduced to idle after one turn.

(7) Recovery Placard. Section 23.1583(e)(3) requires that acrobatic airplanes have a placard listing the use of controls required to recover from spinning maneuvers. Utility category airplanes approved for spins should also have such a placard. Recovery control inputs should be conventional. If special sequences are employed, then they should not be so unique to create a recovery problem.

(8) Complex Instrumentation. When complex instrumentation is installed, such as wing tip booms or a heavy telemetry system, the instrumentation may affect the recovery characteristics. Critical spin tests should be repeated with the instrumentation removed.

e. Data Acquisition. The test airplane should be equipped with a calibrated airspeed indicator, accelerometer, and altimeter. Precise control of weight and balance and control deflections is essential.

f. Optional Equipment. In those cases where an airplane is to be certified with and without optional equipment such as deicing boots, asymmetric radar pods, outer wing fuel tanks, or winglets, sufficient tests should be conducted to ensure compliance in both configurations.

101.-105. RESERVED.

## Section 9. GROUND AND WATER HANDLING CHARACTERISTICS

### 106. SECTION 23.231 (original issue) LONGITUDINAL STABILITY AND CONTROL.

#### a. Explanation.

(1) For landplanes, §§ 23.231(a) and 23.233 are companion requirements to § 23.75.

(2) For floatplanes, §§ 23.231(b) and 23.233 are companion requirements to § 23.75.

(3) The requirements for both landplanes and floatplanes apply to amphibians.

b. Procedures.

(1) Landplanes should be operated from all types of runways applicable to the type of airplane. Taxi, takeoff, and landing operations should be evaluated for acceptable characteristics. This should include idle power landings as well as landings and takeoffs with procedures used in §§ 23.75 and 23.51.

(2) Floatplanes should be operated under as many different water conditions as practical up to the maximum wave height appropriate to the type of airplane. Taxi (both displacement and step), takeoff, and landing operations should be evaluated for acceptable characteristics. This includes idle power landings as well as landings and takeoffs with procedures used under §§ 23.75 and 23.51.

(3) Amphibians should be evaluated in accordance with both items (1) and (2) above.

c. Procedures - Multiengine Airplanes. Evaluate all of the considerations contained in paragraph 106b, plus the effects of one engine loss during water operations.

d. Airplane Flight Manual (AFM). The AFM should include appropriate limitations plus demonstrated wind and sea state conditions.

107. SECTION 23.233 (original issue) DIRECTIONAL STABILITY AND CONTROL.

a. Explanation.

(1) Crosswind. This regulation establishes the minimum value of crosswind that must be demonstrated. Since the minimum required value may be far less than the actual capability of the airplane, higher values may be tested at the option of the applicant. The highest 90° crosswind component tested satisfactorily should be put in the AFM as performance information.

(2) Ground Loops. Section 23.233(a) does not preclude an airplane from having a tendency to ground loop in crosswinds, providing the pilot can control the tendency using engine power, brakes, and aerodynamic controls. The operating procedures should be placed in the AFM in accordance with § 23.1585(a).

(3) Controllability. Section 23.233(b) is not related to the crosswind requirement of § 23.233(a). The demonstration of compliance with this requirement is accomplished into the wind. The test pilot is searching for any unusual controllability problems during landing and must use judgment as to what constitutes "satisfactorily controllable" since, at some point in the landing rollout, the aerodynamic controls may become ineffective.

(4) Taxi Controllability. Section 23.333(c) requires the airplane to have adequate directional controllability for taxi operations on land for landplanes, on water for floatplanes, and on land and water for amphibians.

b. Procedures.

(1) Crosswind.

(i) The airplane should be operated throughout its approved loading envelope at gradually increasing values of crosswind component until a crosswind equivalent to  $0.2 V_{SO}$  is reached. All approved takeoff and landing configurations should be evaluated. Higher crosswind values may be evaluated at the discretion of the test pilot for AFM inclusion.

(ii) For floatplanes, the use of water rudders or the use of airplane attitude on the water to control weathervaning should be described in the AFM.

(2) Controllability.

(i) A landplane should demonstrate satisfactory controllability during power off (idle power) landings through landing rollout. This may be conducted into the existing wind and should be evaluated at all key loading envelope points.

(ii) Although power off landings are not expressly required for floatplanes under § 23.233(b), it is recommended they be evaluated.

(3) Taxi Controllability.

(i) A landplane should have sufficient directional control available through the use of nose/tail wheel steering, differential braking (if provided), differential power (multi-engine airplanes), and aerodynamic control inputs to allow taxiing at its "maximum demonstrated crosswind" value.

(ii) A floatplane should have sufficient directional control available through the use of water rudders, airplane attitude (displacement or plow), taxi technique (displacement or step), differential power (multi-engine floatplanes) and aerodynamic control inputs to allow taxiing at its "maximum demonstrated crosswind" value. This is not intended to suggest that all of the above must be evaluated at  $0.2 V_{SO}$ , but that accepted techniques using one or more of the above must allow controllable taxiing.

(iii) Amphibians should exhibit suitable directional controllability on both land and water in accordance with the preceding two paragraphs. In addition, amphibians should have suitable directional controllability to taxi from the water to a land facility and vice-versa unless prohibited by the operating limitations.

c. Data Acquisition and Reduction. The determination of compliance is primarily a qualitative one. However, wind readings (velocity and direction) should be taken and compared to the wind component chart (appendix 7) to determine that the minimum  $90^\circ$  crosswind component has been tested.

108. SECTION 23.235 (original issue) TAXIING CONDITION.

a. Explanation. This requirement says the airplane landing gear shock absorbing mechanism must function as intended throughout the expected operating envelope of the airplane.

b. Procedures. During the development and certification flight testing the airplane should be operated on a variety of runways including those considered to be the worst (in terms of roughness) appropriate to the type of airplane. There should be no evidence of damage to the airplane during these operations.

109. SECTION 23.239 (original issue) SPRAY CHARACTERISTICS.

a. Explanation. This rule is intended to ensure that any spray produced during floatplane operation does not excessively interfere with the pilot's visibility nor damage beyond "normal wear-and-tear" the airplane itself.

b. Procedures.

(i) Taxi, takeoff, and landing operations should be conducted throughout the approved loading envelope. Spray patterns should be specifically noted with respect to visibility and their contract areas on the airplane. These areas should be monitored to assure compliance with the rule.

(ii) Airplanes with reversing propellers should be demonstrated to comply at the highest reverse power expected to be applicable to the airplane operation.

110.-119. RESERVED.

## Section 10. MISCELLANEOUS FLIGHT REQUIREMENTS

120. SECTION 23.251 (original issue) VIBRATION AND BUFFETING.

a. Explanation.

(1) Flutter. The test required under this section should not be confused with flutter tests which are required under § 23.629. No attempt is made to excite flutter, but this does not guarantee against encountering it. Therefore, the test should be carefully planned and conducted.

(2) Test Speeds. Prior to the test, the pilot should coordinate with the airframe engineer to determine that the flutter requirements of § 23.629 have been satisfied and to determine the most critical weight and c.g. for the test. The flight test engineer and pilot should obtain from the airframe engineer the dive equivalent airspeed and Mach number to which the test should be conducted. Knowing the Mach number and equivalent airspeed, a schedule of pressure altitude and indicated airspeed should be developed for the test.

(3) Airspeed Determination. Another major consideration is calibrated airspeed determination during the test. In this regard, a calibrated, sensitive airspeed indicator should be installed to provide accurate readability. Careful

study of the airplane's airspeed position error/correction curve is required with respect to the characteristics of the slope at the high speed end and how the airspeed calibration was conducted. This is necessary to determine the adequacy of the airspeed position error curve for extrapolating to  $V_D/M_D$ . Refer to appendix 7, figure 5, for compressibility corrections. An expanded Mach No.-calibrated airspeed graph may be found in the Air Force "Flight Test Engineering Handbook" (see appendix 2, paragraph f(2) of this AC).

(4) Springs. If the airplane incorporates spring devices in any of the control systems, the test should be conducted with the spring devices connected and disconnected. Alternately, if satisfactory spring reliability is shown in accordance with § 23.687, tests with springs disconnected are not required. Also see paragraph 45 of this AC.

(5) Mach Limits. For those airplanes that are observing Mach limits, the tests should be repeated at  $M_D$  speed. Careful selection of the test altitude for both  $M_D$  and  $V_D$  tests will help cut down on the number of repeat runs necessary to determine compliance. Attempting to combine the tests at the knee of the airspeed/Mach curve should be approached cautiously since it can result in overshooting the desired speed.

#### b. Procedures.

(1) Configuration. In the clean configuration at the gross weight, most critical c.g. (probably most aft) and the altitude selected for the start of the test, the airplane should be trimmed in level flight at maximum continuous power. Speed is gained in a dive in gradual increments until  $V_D/M_D$  is attained. The airplane should be trimmed if possible throughout the maneuver. Remain at the maximum speed only long enough to determine the absence of excessive buffet, vibration, or controllability problems.

(2) Flaps extended. With flaps extended and the airplane trimmed in level flight at a speed below  $V_{FE}$ , stabilize at  $V_{FE}$  in a shallow dive and make the same determinations as listed above.

### 121. SECTION 23.253 (as amended by amendment 23-26) HIGH SPEED CHARACTERISTICS.

#### a. Explanation.

(1) Related Sections. The design dive speeds are established under the provisions of § 23.335, with the airspeed limits established under the provisions of § 23.1505. There is distinction made in both regulatory sections for airplanes that accelerate quickly when upset. The high speed characteristics in any case should be evaluated by flight demonstration. Section 23.1303(e) gives the requirements for a speed warning device.

(2) Dynamic Pressure and Mach. In general, the same maneuvers should be accomplished in both the dynamic pressure ( $q$ ) and Mach ( $M$ ) critical ranges. All maneuvers in either range should be accomplished at thrust and trim points appropriate for the specific range being evaluated. It should be realized that some maneuvers in the Mach range may be more critical for some airplanes due to drag rise characteristics.

(3) Flight Crew Duties. The airplane's handling characteristics in the high speed range should be investigated in terms of anticipated action on the part of the flight crew during normal and emergency conditions. Consideration should be given to their duties which not only involve piloting the airplane, but also the operational and navigational duties having to do with traffic control and record keeping necessary to the progress of safe flight.

(4) Upset Axes. The upset criteria of § 23.335(b)(4) is predicated on an upset in pitch while operational evaluation of upsets expected to occur in service should cover pitch, roll, yaw, and critical combinations of multiaxis upsets.

(5) Factors. The following factors are involved in the flight test investigation of high speed characteristics:

(i) Effectiveness of longitudinal control at  $V_{MO}/M_{MO}$  and up to the demonstrated  $V_D/M_D$  speed.

(ii) Effect of any reasonably probable mistrim on upset and recovery.

(iii) Dynamic and static stability.

(iv) The speed increase that may result from likely mass movement that occurs when trimmed at any cruise speed to  $V_{MO}/M_{MO}$ .

(v) Trim changes resulting from compressibility effects. Evaluation should cover Mach tuck, control reversal, or other phenomena associated with high speed.

(vi) Characteristics exhibited during recovery from inadvertent speed increase.

(vii) Upsets due to turbulence (vertical, horizontal, and combination gusts).

(viii) Effective and unmistakable aural speed warning at  $V_{MO}$  plus 6 knots, or  $M_{MO}$  plus 0.01M.

(ix) Speed control during application of devices (power, speed brakes, high speed spoilers, etc.).

(x) Characteristics and controllability during and after failure or malfunction of any stability augmentation system.

(6) Type of Warning. Operational experience has revealed that an important and effective deterrent to inadvertent overspeeding is an aural warning device, which is distinctively different from aural warning used for other purposes. Aerodynamic buffeting is influenced by, and is similar to, the effects of turbulence at high speed and is not normally considered to be suitable as an overspeed warning.

(7) Speed Margins. Once it is established whether the airplane limits will be  $V_{NE}$  or  $V_{MO}$ , appropriate speed margins and markings may be evaluated. The factors outlined in § 23.335 have been considered in establishing minimum speed margins during past type certification programs for the appropriate speeds. The factors to be considered are:

- (i) Increment allowance for gusts (0.02M).
- (ii) Increment allowance for penetration of jet stream or cold front (0.015M).
- (iii) Increment allowance for production differences of airspeed systems (0.005M), unless larger tolerances or errors are found to exist.
- (iv) Increment allowance for production tolerances of overspeed warning errors (0.01M), unless larger tolerances or errors are found to exist.
- (v) Increment allowance  $\Delta M$ , due to speed overshoot from  $M_{MO}$  established by upset during flight tests in accordance with § 23.253, should be added to the values for production differences and equipment tolerances, and the minimum acceptable combined value should not be less than 0.05M between  $M_{MO}$  and  $M_D$ . The value of  $M_{MO}$  should not be greater than the lowest value obtained from each of the following equations and from § 23.1505:
 
$$M_{MO} = M_D - \Delta M - .005M - .01M$$

$$\text{or } M_{MO} = M_D - .05M$$
- (vi) Altitudes where  $q$  is limiting, the allowances of items (i) and (ii) are applicable and the Mach increment is converted to the units used for the limits.
- (vii) At altitudes where  $q$  is limiting, the increment allowance for production differences of airspeed systems and production tolerances of overspeed warning errors are 3 and 6 knots, respectively, unless larger differences or errors are found to exist.
- (viii) Increment allowance  $\Delta V$ , due to speed overshoot from  $V_{MO}$  established by upset during flight tests in accordance with § 23.253, should be added to the values for production differences and equipment tolerances. The value of  $V_{MO}$  should not be greater than the lowest obtained from the following:

$$V_{MO} = V_D - \Delta V - 3 \text{ knots (prod. diff.)} - 6 \text{ knots (equip. tol.)}$$

or for  $V_{NO}$  airplanes:

$$V_{NO} = V_D - \Delta V - 3 \text{ knots (prod. diff.)} - 6 \text{ knots (equip. tol.)}$$

b. Procedures. Using the  $V_{MO}/V_{NO}$ ,  $M_{MO}$ , or the associated design or demonstrated dive speeds determined in accordance with §§ 23.251, 23.335, and 23.1505, the airplane should be shown to comply with the high speed characteristics of § 23.253 and that adequate speed margins exist. Unless otherwise stated, the airplane characteristics should be investigated at any likely speed up to and including  $V_{NO}/V_{MO}$  or  $M_{MO}$ ; and the recovery procedures used should be those selected by the applicant, except that the normal acceleration during recovery should be 1.5g (total).

(1) Center-of-Gravity Shift. The airplane should be upset by the center-of-gravity shift corresponding to the forward movement of a representative number of passengers depending upon the airplane interior configuration. The airplane should be allowed to accelerate for 3 seconds after the overspeed indication or warning occurs before recovery is initiated. Note the maximum airspeed. Do not exceed  $V_D/M_D$ .

(2) Inadvertent Control Movement. Simulate an evasive control application when trimmed at  $V_{MO}/M_{MO}$  by applying sufficient forward force to the elevator control to produce 0.5g (total) for a period of 5 seconds, after which recovery should be effected at not more than 1.5g (total). Care should be taken not to exceed  $V_D/M_D$  during the entry maneuver.

(3) Gust Upset.

(i) Lateral Upset. With the airplane trimmed at any likely cruise speed up to  $V_{MO}/M_{MO}$  in wings level flight, perform a lateral upset to the same angle as that of the autopilot approval, or to a maximum bank angle appropriate to the airplane, whichever is critical. Operationally, it has been determined that the maximum bank angle appropriate for the airplane should not be less than  $45^\circ$ , need not be greater than  $60^\circ$ , and should depend upon airplane stability and inertia characteristics. The lower and upper limits should be used for airplanes with low and high maneuverability, respectively. Following this, with the controls free, the evaluation should be conducted for a minimum of 3 seconds after  $V_{MO}/M_{MO}$  or 10 seconds, whichever occurs first.

(ii) Longitudinal Upset. Perform a longitudinal upset from normal cruise by displacing the attitude of the airplane (nose down from the trimmed attitude) in the range between  $6-12^\circ$ , which has been determined from service experience to be an optimum range. The value of displacement should be appropriate to the airplane type and should depend upon airplane stability and inertia characteristics. The lower and upper limits should be used for airplanes with low and high maneuverability, respectively. The airplane should be permitted to accelerate until 3 seconds after  $V_{MO}/M_{MO}$ .

(iii) Two-Axis Upset. Perform a 2-axis upset consisting of a longitudinal upset combined with a lateral upset. Perform a longitudinal upset by displacing the attitude of the airplane as in the previous paragraph, and simultaneously perform lateral upset by rolling the airplane to the  $15-25^\circ$  bank angle range, which was determined to be operationally representative. The values of displacement should be appropriate to the airplane type and should depend upon

airplane stability and inertia characteristics. The lower and upper limits should be used for airplanes with low and high maneuverability, respectively. The established attitude should be maintained until the overspeed warning occurs. The airplane should be permitted to accelerate until 3 seconds after  $V_{MO}/M_{MO}$ .

(4) Leveling Off From Climb. Perform transition from climb to level flight without reducing power below the maximum value permitted for climb until the overspeed warning has occurred. Recovery should be accomplished by applying not more than 1.5g (total).

(5) Descent From Mach to Airspeed Limit Altitude. A descent should be initiated at  $M_{MO}$  and performed at the airspeed schedule defined in  $M_{MO}$  until the overspeed warning occurs. The airplane should be permitted to descend into the airspeed limit altitude where recovery should be accomplished after overspeed warning occurs by applying not more than 1.5g (total). The maneuver should be completed without exceeding  $V_D$ .

122.-131. RESERVED.